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MetCon

# Voltage-to-Freq Assembly Manual

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## INTRODUCTION

The TAPR V-to-F (Voltage-to-Frequency Convertor) is an accessory to the METCON product. It is used for measuring voltages and temperatures at a remote site for reporting via packet radio. When completed, it should deliver years of high-performance service.

This kit contains all parts and components necessary to populate the METCON V-to-F printed circuit (PC) board. There is no cabinet. case, or power supply included or available from TAPR.

If you ordered a temperature option, those parts will be included in this kit and directions for their assembly are included in this manual.

Please follow the directions in this manual carefully. It has been revised based on feedback from numerous builders.

Don't forget to carefully inspect the carton in which this kit came for any last-minute additions/ corrections to the instructions provided in this manual.

As always, if you find errors or have questions or suggestions for this kit, please write or fax the TAPR office. If you have technical support questions, refer to the "IMPORTANT! Read Me First!" insert.

If you exercise care, construction of this kit should take you from one (1) to three (3) hours, depending on your experience.

So, clear off your workbench, warm up your soldering iron, and enjoy!

## PARTS LIST

Sort the parts into egg cartons, muffin tins, or other containers as you inventory them. This will aid you in building.

Check off the part in the ( ) space provided as you locate and verify it against this list.

### Capacitors

Ceramic, Monolithic

| | | | |
|---|---|---|---|
| ( ) 01 | 330 pF | 331 | MONO-331C |
| ( ) 01 | 3300 pF | 332 | MONO-332C |
| ( ) 03 | 0.01 uF | 103 | MONO-103Z |
| ( ) 01 | 0.1 uF | 104 | MONO-104Z |
| ( ) 01 | 1 uF | 105 | MONO-105X |

Electrolytic, Radial lead

| | | | |
|---|---|---|---|
| ( ) 01 | 10 uF | 106 | RAD16V-106 |

### Connectors

| | | |
|---|---|---|
| ( ) 01 | 2-position wire-clamp | RDI2SV |
| ( ) 01 | 4-position wire-clamp | RDI4SV |
| ( ) 03 | 2 pin male headers | HDR-02M |

### Diodes

| | | |
|---|---|---|
| ( ) 01 | 1N4002 | 1N4002 |
| ( ) 01 | 1N4148 | 1N4148 |

### ICs

ICs are inserted in anti-static foam. Please do not remove them until they are called out in the construction steps that follow.

ICs often contain many numbers, and the "core" number may have a prefix and / or a suffix. A 74HC14, for example, may be marked MC74HC14P or SN74HC14N.

A four-digit number starting with 90, 91, or 92 is probably a date code, not the part number. A date code might be 9123 or 9004.

| | | |
|---|---|---|
| ( ) 01 | 4013B Dual D Flip-Flop | CD4013BE |
| ( ) 01 | 4N26 Opto Coupler | 4N26 |
| ( ) 01 | LM331N V to F Convertor | LM331N |
| ( ) 01 | LM358N Dual Op-Amp | LM358N |
| ( ) 01 | LM34 (Fahrenheit) Temp Sensor | LM34 |
| or | LM35 (Centigrade) Temp Sensor | LM35 |

## Resistors

1 / 4 Watt, 5% Carbon Film

| | | | |
|---|---|---|---|
| ( ) 01 | 47 ohm | (yellow-violet-black-gold) | CFR1 / 4-470 |
| ( ) 01 | 1K ohm | (brown-black-red-gold) | CFR1 / 4-102 |
| ( ) 01 | 10K ohm | (brown-black-orange-gold) | CFR1 / 4-103 |
| ( ) 01 | 22K ohm | (red-red-orange-gold) | CFR1 / 4-223 |
| ( ) 01 | 33K ohm | (orange-orange-orange-gold) | CFR1 / 4-333 |
| ( ) 01 | 100K ohm | (brown-black-yellow-gold) | CFR1 / 4-104 |
| ( ) 01 | 10K ohm | (brown-black-orange-gold) | CFR1 / 4-103 |

1 / 8 watt, 1% metal film

| | | | |
|---|---|---|---|
| ( ) 02 | 10K ohm | (brown-black-black-red-brown) | |
| | | or 1002 | MFR1 / 8-1002 |
| ( ) 02 | 100K ohm | (brown-black-black-orange-brown) | |
| | | or 1003 | MFR1 / 8-1003 |
| ( ) 01 | 249K ohm | (red-yellow-white-orange-brown) | |
| | | or 2493 | MFR1 / 8-2493 |
| ( ) 01 | 909K ohm | (white-black-white-orange-brown) | |
| | | or 9093 | MFR1 / 8-9093 |
| ( ) 01 | 90.9K ohm | (white-black-white-red-brown) | |
| | | or 9092 | MFR1 / 8-9092 |
| ( ) 01 | 100K ohm | (brown-black-black-orange-brown) | |
| | | or 1003 | MFR1 / 8-1003 |

3 / 8" multi-turn trimpot

| | | | |
|---|---|---|---|
| ( ) 01 | 20K ohm | 203 | TRIM-203 |
| ( ) 01 | 20K ohm | 203 | TRIM-203 |

## Transistor

| | | |
|---|---|---|
| ( ) 01 | 2N3904 | 2N3904 |

## IC Sockets

| | | |
|---|---|---|
| ( ) 01 | 06 pin | DIPS-06 |
| ( ) 01 | 08 pin | DIPS-08 |
| ( ) 01 | 14 pin | DIPS-14 |
| ( ) 01 | 08 pin | DIPS-08 |

## Miscellaneous

( ) 03 push-on jumper
( ) 01 VtoF PC Board
( ) 01 VtoF Assembly Manual

# CONSTRUCTION

Note that the PC board has two trace sides with plated-through holes joining them. This means that you must use a temperature-controlled soldering iron, fine 60 / 40 or 63 / 37 rosin core solder, and painstaking care when making each and every joint. The reward will be a superior device of excellent reliability. The alternative will most likely be erratic operation.

In addition to the soldering iron and solder, you will need small flush or semi-flush cutting pliers and small-tipped long nosed pliers. A magnifying glass may prove helpful to identify the values of the small components. A lead-bending jig will help maintain a neat appearance for the resistors and other axial leaded parts.

Pay careful attention to the directions that follow. Keep the tip of your soldering iron bright and clean, wiping it frequently on a wet rag or sponge. Make solder joints carefully, but swiftly. Prolonged heat on a PC board pad can be as disastrous as too much heat, and ruining this PC board can be expensive! Two to three seconds should be enough time to apply heat to any joint.

## IC SOCKETS

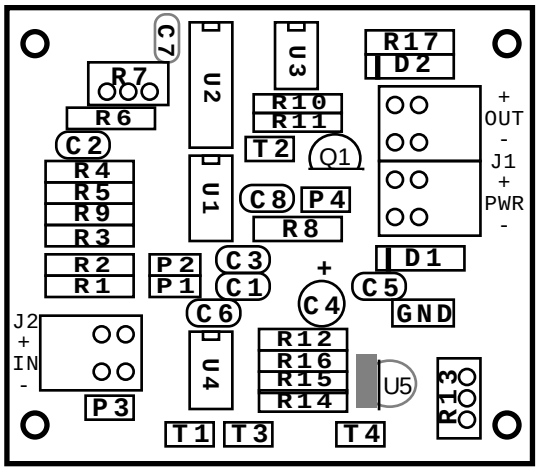
Check the PC board to make sure that the exposed, tinned pads are clean and shiny. If they are not, scrub the board lightly with a household cleanser (such as Ajax or Comet), rinse in fresh, clean water then dry with a soft towel.

( ) PC board clean.

Component installation will generally proceed from left to right and top to bottom of the PC board when the board is held so that the silkscreen legend "METCON V to F" is in the lower right-hand corner of the PC board.

*NOTE: IC sockets are polarized. The end nearer pin 1 is marked with a notch, a beveled corner, or the numeral "1" embossed in the plastic body of the socket. The PC board silkscreen is marked with a notch at the pin 1 end.*

*When installing an IC socket, be sure all pins are through the PC board, then tack solder a diagonally opposite pair of pins. Double check that the socket is flush against the PC board surface and that all pins are through, then solder the remaining pins. Finally, re-solder the original two tack-soldered pins.*




Install the following parts:

( ) U2 socket 14 pin
( ) U3 socket 06 pin
( ) U1 socket 08 pin
( ) U4 socket 08 pin

Solder connections should appear bright and shiny, with a concave fillet between the PC board pad and the socket pin. Gray, grainy-looking joints, round solder blobs or pads not completely and evenly covered with solder will result in an unreliable joint. These joints should be re-soldered, using a good grade of rosin-core flux to ensure the joint is clean and that the solder adheres.

Now, double check the solder connections you have made.

( ) Solder joints OK.

Take this opportunity to verify that there are no leftover IC sockets.

( ) No IC sockets remaining.

## RESISTORS

Resistors used in this kit are in three forms: discrete, axial-leaded carbon resistors, discrete axial-leaded metal film (precision) resistors, and multi-turn trimpots.

Due to space limitations and other conflicts, all resistor locations on the PC board may not have the identifier printed on the board. The illustrations in this manual will identify the locations of all resistors, so continue to pay close attention to the manual and the PC board.

Discrete resistors have color-coded bands denoting their value. The color code will be given in each step to aid you in identifying the value. If you have any doubt about a resistor's value, we suggest you measure it with an ohmmeter before you install it. We have tried to limit the number of different values, but it is better to be careful than to try and remove and reinstall a resistor on a plated-through-hole PC board!

When installing discrete resistors, bend the leads and then insert the resistor so that its body is flush with the PC board surface. Then bend the leads slightly to secure it in place. If you are using a lead-bending jig, resistor leads are on 0.5" (12.7 mm) centers. After placing a number of resistors, you will be instructed to solder the leads and clip the excess lead lengths. At that time a count of solder joints will be given as an aid to ensure you don't overlook a lead or two.

Some precision resistors may have the value printed on the body of the part. A 10,000 ohm device might be identified with the number series "1002" or "10K" instead of a color code. Again, be sure of the component before you solder it on the board. Number series for 1% resistors are included in the parts list along with their color coding..

In the steps that follow, be careful to use 1% precision resistors only when called for, and carbon film resistors (5%) at all other times.

Install the following resistors:

( ) R6 10K 1% (brown-black-black-red-white) or 1002
( ) R4 100K 1% (brown-black-black-orange-white) or 1003
( ) R5 47 ohm (yellow-violet-black-gold)
( ) R9 10K (brown-black-orange-gold)
( ) R3 100K 1% (brown-black-black-orange-white) or 1003
( ) R2 909K 1% (white-black-white-orange-white) or 9093
( ) R1 249K 1% (red-yellow-white-orange-white) or 2493

( ) Solder and clip fourteen (14) leads.

( ) R17 33K (orange-orange-orange-gold)
( ) R10 22K (red-red-orange-gold)
( ) R11 1K (brown-black-red-gold)
( ) R8 10K 1% (brown-black-black-red-white) or 1002

( ) R12 90.9K 1% (white-black-white-red-white)
or 9092
( ) R16 10K (brown-black-orange-gold)
( ) R15 100K (brown-black-yellow-gold)
( ) R14 100K 1% (brown-black-black-orange-white)
or 1003

( ) Solder and clip eight (8) or sixteen (16) leads.

( ) No discrete resistors remaining.

**Carefully inspect the board for any poor solder joints, and correct any that you find.**

( ) All solder connections look simply wonderful!

The trimpots will be installed later.

## CAPACITORS

The next components to be installed are capacitors. These come in ceramic monolithic radial-leaded devices which are non-polarized, and electrolytic radial-leaded devices which are polarized. You will first install the ceramic, non-polarized parts.

### CERAMIC CAPACITORS

These parts should be mounted close to the top surface of the PC board. You will be instructed when to solder, so just install parts and secure by bending leads until then. You may need to straighten or bend some leads to make them fit the PC board hole spacings.

Install the following parts:
( ) C7 0.01 uF (103)
( ) C2 1 uF (105)
( ) C8 3300 pF (332)
( ) C3 330 pF (331)
( ) C1 0.1 uF (104)
( ) C6 0.01 uF (103)
( ) C5 0.01 uF (103)

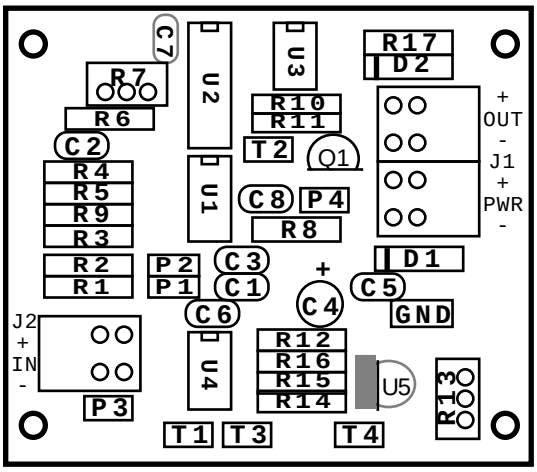
( ) Solder and clip fourteen (14) leads.

You should have no ceramic capacitors remaining.

( ) All ceramic capacitors have been used.

## POLARIZED CAPACITORS

The next component you will install is the polarized capacitor. This may be an aluminum electrolytic or tantalum type.




Electrolytic capacitors are cylindrical with radial leads (meaning both leads come out one end). The negative lead is usually marked with a black band filled with minus signs. In addition, this lead is usually shorter than the positive one.

Tantalum capacitors, in addition to having incredibly small, hard to read print, mark the positive lead with little plus signs on one side of the part. Tantalums are usually a sort-of teardrop shape.

The PC board silkscreen is marked with a plus (+) sign near the positive lead. The positive lead pad is square.

Be sure to get the positive lead in the square pad, no matter which type of part you are installing.

Install the following part:
( ) C4 10 uF (106)

( ) Solder and clip two (2) leads.

## REMAINING COMPONENTS

You will now be instructed to install the remaining parts on the PC board. Some of these parts are polarized, so continue to pay careful attention to the directions.

### Diodes

Diodes are polarity sensitive. The cathode is marked on the PC board silkscreen with a band at one end. The diode similarly has a band at the cathode end. The cathode lead also has a square pad on the PC board.

The two diode types used on the V-to-F are similar in appearance, but very different in characteristics and application. Match the part number of the diode to the callout before soldering.

Install the following parts:
( ) D2 1N4148 (cathode left)
( ) D1 1N4002 (cathode left)

( ) Solder and clip four (4) leads.

## Trimpots

Trimpots have the value printed on the body of the part. A 10,000 ohm network might be identified with the number series "203" or "20K". Again, be sure of the component before you solder it on the board.

When installing trimpots, solder them at each step. There is not enough lead length to secure the part mechanically before soldering. Orient the adjustment screw at the pin 1 (square pad) end of the part outline. Tack solder the center pin, verify the part is properly seated on the PC board, then solder the remaining pins. Next, re-solder the tack-soldered pin. clip the excess lead lengths and inspect the solder connections before proceeding on to the next trimpot.

Install the following parts:
( ) R7 20K or 203
( ) R13 20K or 203

## Headers

The single-row headers are used to allow jumper selection of various operational configurations.

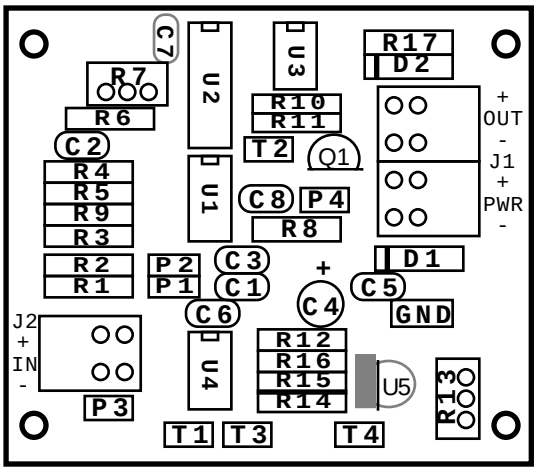
When soldering one of these headers to the PC board, hold it against the board with your finger while you tack-solder a pin to the board (small headers).

*NOTE: Do not solder the pin which you are holding with your finger! The pins quickly get very hot and you may injure yourself!*

After you tack-solder the header in place, inspect it for mechanical placement and appearance. It should sit firmly against the surface of the PC board and rise perpendicularly from it. If it doesn't, re-heat the tacked joint (s) and re-position the part until you are satisfied with it. Then solder the remaining pins. Finally, re-solder the tack-soldered connection(s).

Install the following parts:
( ) P4 02-pin header
( ) P2 02-pin header
( ) P1 02-pin header
( ) P3 02-pin header

( ) Inspect the solder connections and repair any that aren't perfect.




## Transistor and U5

These parts are in a three-lead TO92 plastic-bodied case. The parts should match up with the silkscreen outlines. The body of the part should be about 1/4" (6mm) above the board surface.

( ) Q1 2N3904
( ) U5 LM34 (Fahrenheit) or LM35 (centigrade)

( ) Solder and clip three (3) [or six (6)*] leads.

## Connectors

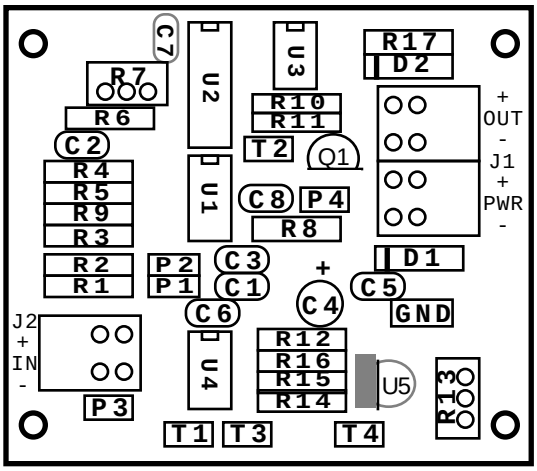
V-to-F uses wire-clamp connectors for off-board connections. The wire-clamp connectors should be mounted flush to the PC board surface and with the wire-entry ports to the outside edge of the PC board.

To mount, line up the body of the connector with the silkscreen outline. The silkscreen labels should be plainly visible after the connector is positioned. You will only use 1/2 of the provided holes in the PC board — the pattern on the board will accept a number of styles of connectors from a variety of sources, so don't worry about the empty holes!

Solder the pins on each connector before proceeding to the next one.

Install the following connectors:
( ) J2 2-position wire-clamp
( ) J1 4-position wire-clamp

Test points are provided for checking the power supply as well as providing convenient places to clip test leads when troubleshooting V-to-F. Test points are made by forming a cut off component lead around a 1/8" (3mm) drill bit, then placing the resulting loop of wire through the two holes in the PC board provided. The loop of wire then serves as the test point or grounding point for an oscilloscope probe or other test device.




Solder the wires and clip them as you install each test point.

| | | |
|---|---|---|
| ( ) | T2 | test point - loop |
| ( ) | GND | test point - loop |
| ( ) | T1 | test point - loop |
| ( ) | T3 | test point - loop |
| ( ) | T4 | test point - loop |

*You should have no remaining connectors or other PC mounted components.*

You have completed all soldering operations on the PC board. At this point, you should take a break for at least five or ten minutes and relax.

---

Now that you are back, you need to perform a careful inspection of the PC board. Now, once again inspect each of the solder connections, preferably with a magnifying glass. We cannot over-emphasize the importance of these connections.

( ) All solder joints inspected and look great to me!

You also need to carefully inspect the top of the board in case some solder accidentally found its way through the holes and flowed to cause a short circuit somewhere. Or, perhaps a component got damaged while work was proceeding elsewhere on the board. It is better to find and fix all such problems now.

( ) This board is inspected and looks good.

*You should have three (3) push on jumpers and three (3) or four (4) ICs remaining.*

# Initial Test

( ) Observing anti-static precautions, install the ICs:

| | |
|---|---|
| U2 | 4013B |
| U3 | 4N26 |
| U1 | LM331 |
| U4 | LM358 |

Now, connect power to the V-to-F and prepare to calibrate it. The following steps assume you have a frequency counter available as well as a voltmeter of at least 1% accuracy.

*NOTE: If you lack a frequency counter, you may wire the J1 +OUT to METCON IN0 and J1 -OUT to METCON GND and use the frequency measurement function of METCON to measure the frequency.*

( ) Clamp a wire from V-to-F J1 **+PWR** to a source of +12 VDC.

( ) Clamp a wire from V-to-F J1 **-PWR** to the return lead of the 12 VDC source.

# Calibration

The V-to-F may be configured for either **HIGH** voltage range inputs (0 to +100 VDC), **LOW** voltage range inputs (0 to +10 VDC), or **temperature**. The sections below discuss the different calibration procedures for these three configurations.

## High Voltage Range Calibration

To configure the V-to-F for the HIGH voltage range:

( ) Install a shorting plug at P2 and P4. Ensure that no shorting plugs are installed at P1 or P3.

( ) Apply a voltage of precisely 50.0 VDC to +IN and -IN

( ) Connect a frequency counter to T2.

( ) Adjust R6 for a frequency counter indication of 5000 Hz.

## Low Voltage Range Calibration

To configure the V-to-F for the LOW voltage range:

( ) Install a shorting plug at P1 and P4. Ensure that no shorting plugs are installed at P2 or P3.

( ) Apply a voltage of precisely 5.00 VDC to the input.

( ) Connect a frequency counter to T2.

( ) Adjust R6 for a frequency counter indication of 5000 Hz.

## Temperature Calibration

First, you must determine if you want temperature in Fahrenheit or Celsius units. Install an LM34 at IC5 for Fahrenheit, or an LM35 at IC5 for Celsius.

( ) Install a jumper at P1, P3, and P4. Ensure that no jumper is installed at P2.

( ) Connect a digital voltmeter to T3 (+) and ground (-).

( ) Adjust R14 for precisely +1.000 volt indication on the digital voltmeter.

( ) Connect the digital voltmeter to T4 (+) and T3 (-).

( ) Connect a frequency counter to T2.

( ) Take the voltage measured by the voltmeter, in volts, and multiply this value by 1000 and then add 1000 and call it F- WANTED. (See below for details of this calculation.)

( ) Adjust R7 for an indication of F- WANTED Hz on the frequency counter.

The frequency output by VTFCS now reads in tenths of degrees with a +100 degree offset.

# Temperature Calculation Examples

This section includes examples showing how to convert frequency measurements to temperature. The units of temperature are Fahrenheit if IC5 is an LM34 or Celsius if IC5 is an LM35.

Example 1

Q. The frequency measured is 1683, what is the temperature?

A. Divide the frequency by ten (168.3) and then subtract 100 (68.3) for a temperature of +68.3 degrees.

Example 2

Q. The frequency measured is 783, what is the temperature?

A. Divide the measured frequency by ten (78.3) and then subtract 100 (-21.7) for a temperature of -21.7 degrees.

# Positive Only Temperatures

If you don't expect to deal with negative temperatures, you can configure the V-to-F to measure without the 100 degree offset. To do this:

( ) Remove IC4.

( ) Install a jumper in the board between the holes for IC4 pin 11 and IC4 pin 7.

( ) Calibrate as before but do not add in the 1000 Hz offset.

*NOTE: Don't bother adjusting R13, it now has no effect.*

Now the frequency measured can simply be divided by ten (10) to determine the temperature.

# V-to-F Functions

This adapter measures an external positive voltage in one of two ranges with an input impedance of 250 kilo-ohms or more. The output consists of an opto-isolator transistor that can amplitude modulate an external current source at a frequency proportional to the input voltage.

When configured for HIGH input voltage, the V-to-F accepts signals in the range of 0 to +100 volts with a conversion gain of 100 Hz per volt.

When configured for LOW input, the V-to-F can accept signals in the range of 0 to +10 volts with a conversion gain of 1000 Hz per volt.

The METCON V-to-F can also be configured to measure temperature in Fahrenheit or Celsius, positive only or positive and negative. This is accomplished by installing a temperature sensor and an offset reference circuit (if negative temperatures are expected).

**Voltage Configuration Table**

| InputRange (volts) | P1 | P2 | P3 | P4 |
|---|---|---|---|---|
| 0 - 1 † | X | | | |
| 0 - 10 | X | | | X |
| 0 - 100 | | X | | X |
| TEMP(xxx.x) | X | | X | X |
| TEMP(xx.xx) † | X | | X | |

X denotes shorted connector block
† denotes experimental mode - least significant digit may be inaccurate.

# V-to-F Circuit Description

When configured for 0 to 10 volt inputs, P1 and P4 are shorted while P2 and P3 are open.

When configured for 0 to 100 volt inputs, P2 and P4 are shorted while P1 and P3 are open. C1 is a compensating capacitor to smooth the signal and form a time constant similar to the integrating capacitor C2.

R1, R2 and R3 form a voltage divider that reduces the input signal to either 80% (LOW range) or 8% (HIGH range) of its original value. The use of 80% (or 8%) limits the voltage at the input of IC1 to 8 volts, maximum.

IC1 (LM331) is the voltage to frequency converter.

IC1 will operate correctly provided that the input remains at least 2 volts below the power supply voltage. Thus, with a maximum input voltage of +8 volts, the power supply can be as low as +10 volts, or +10.7 volts at pins 1 and 2 of J1 (accounting for the voltage drop across D1).

Current pulses are sent out from pin 1 of IC1 and integrated by C2. R4 discharges C2 when current is not being supplied by pin 2. R5 provides a hysteresis effect that improves linearity.

R6 and R7 are used to adjust the conversion gain of IC1 and associated components by determining the amount of current output on pin 1.

C3 and C8 determine the length of the current pulses that are output on pin 1.

When P4 is open, C8 is no longer in parallel with C3 thus increasing the gain of IC1 by a factor of 10. P4 is left open when measuring very low voltages such as those from the temperature sensor. However, when P4 is removed, the least significant digit of the frequency reading may be inaccurate. Be cautious about the accuracy of the least significant digit when the shorting plug is removed from P4.

R9 pulls up the open collector frequency output of IC1. Typically, the output of IC1 consists of narrow pulses that are not suitable for transmission over long cable runs.

IC2A (CD4013B) is a D-flip-flop that's configured as a divide by two element. The signal at the output of IC2A pin 1 is a 50% duty cycle signal that can easily travel over twisted pair cable to the monitoring unit. IC2B is configured as an inverter and is used to drive Q1 via R10. (R10 can be lowered in value, if needed, to drive Q1 harder without loading IC2A.)

IC3 (4N26), an opto-isolator, is used to provide isolation between the V-to-F and the monitoring unit.

The V-to-F requires +11 to +15 volts DC for proper operation. The ground of the power source must be common with the signal to be measured. However, there doesn't need to be any common or reference connection between the V-to-F and the monitoring unit. IC3 provides up to a few hundred volts of isolation for this purpose.

# Resistor Tolerances

There are several places on this board where it looks like 1% resistor are specified without good reason (for example, in series with a pot). However, in several places 1% resistors are used because of their stability over temperature instead of their tight absolute tolerance. Don't change these resistor tolerances unless you are not concerned about temperature drift.

# Notes

See the National Semiconductor Data Acquisition Linear Devices Databook for an excellent discussion of how the LM331 chip operates.